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A software development for investment analysis of LED lighting production project using fuzzy logic technique

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ABSTRACT

In this work, an application software for investment decision-making has been developed to analyze the feasibility level of an LED lighting production project. Particularly, the initial, manufacturing, administration, and financial expenses of the project, along with sales income and corporate tax, are applied as financial data. These inputs are then calculated into the net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR), and discounted payback period (DPB) values, and further synthesized into the investment feasibility level using fuzzy logic. Additionally, the software allows flexible discount rate variation throughout project duration. The analysis results of 5 years duration project show that the NPV, IRR, BCR, and DPB were 6,307,759.46 Thai Baht, 24.04%, 1.08, and 3.38 years, respectively. Moreover, with 20% of expected profit margin, the feasibility level of project applying the floating discount rate of 7.12%-8.00% was "medium" at 77.89%, while project with fixed 8.00% rate suggested the level of "medium" at 67.34%. The discount rate variation, further, implied that using the floating discount rate was more attractive for the investment. Sensitivity analysis also revealed that the project was attractive until its income was 3.1% lower and expense was 2.4% higher than original. Therefore, the developed software could be suitable tool for more realistic project feasibility assessment and investment decision-making.

Keywords**:** LED lighting production; economic assessment tools; fuzzy logic; investment decision-making model; small and medium enterprise

1. INTRODUCTION

The lighting technology is, currently, an important need for human life, as 19% of the world's electricity has been consumed by the luminaires (Nardelli et al., 2017). However, this is mostly due to the utilization of the incandescent and fluorescent lamps, which have less lighting efficiencies and short life cycles. This means more energy is consumed and more product waste would be disposed over the years. Therefore, light-emitting diode (LED) has been developed as an alternative luminaires. When compared to conventional fluorescents, LED could provide equivalent luminousity with 2-3 times less energy usage, lower greenhouse gas emission, and longer lifespan (Principi and Fioretti, 2014). As such, LED lighting market have been promoted. In Thailand, the

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growth rate of this market increased from 27.7% in 2015 to 35.8% in 2016 (Ahn et al., 2014). The industrial sector, thus, takes interest in the production of this technology for distribution within the country. In this case, the “LED T8 lamp” has been developed to replace conventional T8 fluorescents with comparable efficiency to other commercial LED lighting with 37.15% lower cost (Lapsongphon and Pullteap, 2018). This promotes the establish of an LED T8 production business. Nevertheless, it is important to assess the economic feasibility to prevent any wasteful investments.

Particularly, net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR), and discounted payback period (DPB), have been widely used for the feasibility analysis. BCR was calculated to investigate the economic feasibility of the mangrove restoration in Bangladesh (Rahman and Mahmud, 2018). NPV and IRR decided the feasibility of ethanol thermochemical production route in Brazil (Taylor-de-Lima et al., 2018). NPV, IRR, and DPB were, also, considered in the feasibility study of the floating offshore windfarm in Spain (Castro-Santos et al., 2016). Moreover, feasibility of rainwater and greywater reuse systems in high demand household was assessed using the aforementioned economic assessment tools (Oviedo-Ocaña et al., 2018). This technique is, however, incapable of suggesting the feasibility level of the project. Certainly, the investor would have to evaluate the worthiness of any given investment project. This causes more uncertainties to arise and would create more risks during the decision-making. Hence, fuzzy logic was introduced to synthesize objective results based on human reasoning. This type of logic has been incorporated for the business decision-making processes throughout the years. For example, Zeng and Xiao (2016) proposed the fuzzy logic technique for multi-criteria decision-making, which allowed an intuitionistic problem-solving schemes. Kiliç and Kaya (2015) demonstrated the fuzzy logic methodology for the evaluation of the investment project. Shen and Tzeng (2015) studied the technical analysis model with the fuzzy logic to enhance the investment decision-making processes. Therefore, applying the fuzzy logic technique in associate with NPV, IRR, BCR, and DPB could improve the investment decision-making.

The investment feasibility analysis model based on the economic assessment tools and fuzzy logic technique has been developed in previous work (Samartkit and Pullteap, 2019). The distinctive point of the model is the ability to synthesize the feasibility level and percentage of any given investment projects, which supports the decision-making of the investor. Consequently, the model is suitable for the investment project with a fixed discount rate, such as large scale investment established by the government. However, small enterprises are incapable of utilizing the constant interest rate. Thus, it is inevitable to consider the floating discount rate that varies depending on the financial institutes. This became the limitation of the designed software. As such, this work proposed the further development of the investment feasibility analysis software by allowing the floating discount rate in each year to be determined. In addition, the investigation of the LED lighting production project was conducted to evaluate the investment feasibility. In this case, the floating discount rate was applied and observed to verify the impact on the feasibility results.

1.1 LED T8 lamp structure and specification

To assess the investment feasibility in this work, the structure and production of the LED T8 lamp have been investigated. This type of tubular LED lighting is designed for the replacement of the T8 fluorescent tubes. In particular, the developed LED T8 lamp has consisted of 5 main components, which are shown accordingly in Figure 1.

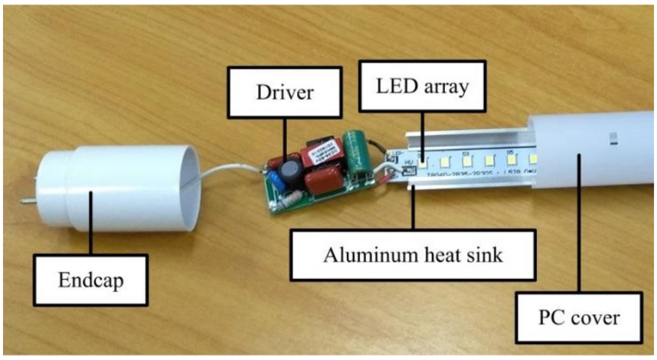

Figure 1 General structure of LED T8

The LED array is comprised of several LED chips, which would illuminate when receiving the electricity (DC voltage), whereas the driver converts the input AC into the usable DC. The aluminum heat sink, however, works as the cooling unit for the electronic components. Meanwhile, the PC cover and endcaps are constructed as the physical protection of the LED tube.

The manufacturing process of the LED T8 lamp has been indicated in 4 important steps, which are the LED array production, LED driver development, components assembly, and product quality control, respectively, as illustrated by Figure 2.

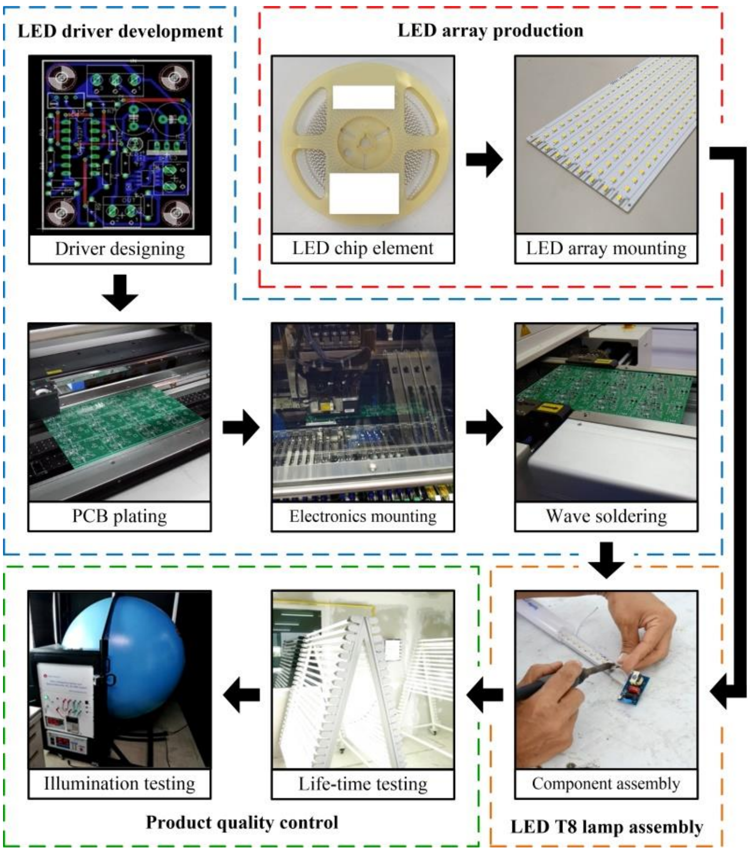

Figure 2 LED T8 lamp manufacturing process

1.2 Economic assessment tools

These tools are widely used for assessing the economic feasibility of an investment project to ensure its possibility of yielding the return back to the investors. In general, it is comprised of four important parameters; the NPV, IRR, BCR, and DPB. The calculations of these important parameters could, therefore, be expressed by (Brealey et al., 2014; Leite et al., 2017; Strnad and Prenc, 2018):

$$\mathrm{NPV} = \sum_{n=1}^{N}\left[\frac{\left(I_n - E_n\right)}{\left(1+r_n\right)^n}\right] - E_0 \quad (1)$$

$$\sum_{n=1}^{N}\left[\frac{\left(I_n - E_n\right)}{\left(1+\mathrm{IRR}\right)^n}\right] - E_0 = 0 \quad (2)$$

$$\mathrm{BCR} = \frac{\sum_{n=1}^{N}\left[I_n / \left(1+r_n\right)^n\right]}{\sum_{n=1}^{N}\left[E_n / \left(1+r_n\right)^n\right] + E_0} \quad (3)$$

$$\mathrm{DPB} = Y + \frac{\left|\sum_{n=1}^{Y}\left[\left(I_n - E_n\right)/\left(1+r_n\right)^n\right] - E_0\right|}{\left(I_{(Y+1)} - E_{(Y+1)}\right)/\left(1+r_n\right)^{(Y+1)}} \quad (4)$$

where I_n is the income of the year n, E_n corresponds to the expense of the year n, E_0 indicates the initial expense, r_n represents the floating discount rate of the year n, n is the project year in consideration (year 1, 2, 3, …, N), N describes the project duration, and Y is the year which the cumulative cash flow is less than "0".

Moreover, the investment project has been considered to be economically feasible when the values of all important parameters match the following criteria, that is:

- The NPV is more than "0" ($\mathrm{NPV} > 0$)
- The IRR is greater than the average of the discount rate ($\mathrm{IRR} > \sum_{n=1}^{N}\left(r_n\right)/N$)
- The BCR is higher than "1" ($\mathrm{BCR} > 1$)
- The DPB is less than the project duration ($\mathrm{DPB} < N$)

The economic assessment tools could not evaluate the worthwhileness of the investment project, as it is subjective to the perspective of each individual. However, the profit margin has been one of the essential indices regarding the investment decision-making. As such, the "expected profit margin (EPM)" has been proposed for the evaluation of the investment worthwhileness, which would be defined as the "feasibility level". This index would be pre-determined by the investor in terms of a percentage value, representing the proportion of profit to the total income of the project. Consequently, the value of EPM affects the feasibility level inversely, i.e., the less value the EPM is, the higher the feasibility level, and in contrast when the EPM has more value.

1.3 Fuzzy logic technique

This particular logic, introduced by Zadeh in 1965, represents the computation of the human reasoning-based variables, which are vague or uncertain by nature (Adnan et al., 2015; Elhosseini et al., 2018). Consequently, it allows computers to process these qualitative data according to the input knowledge from the human user, resulting in the ability of "thinking" like humans, and could be implemented for the decision-making (Mardani et al., 2015). Specifically, fuzzy logic proposes the membership degree to each assigned variables, ranging from "0" to "1", which is different than the completely "True (1)" or "False (0)" concepts (Suganthi et al., 2015). This technique amends for the consideration which requires significant information rather than the scientific data. In a broader perspective, fuzzy logic is comprised of three main operations; fuzzification, fuzzy rule-based inference, and defuzzification, respectively (Goswami and Joshi, 2018), The fuzzification, firstly, describes the translation of the quantitative inputs into the qualitative value, mostly through the application of the fuzzy set and the membership function. To clarify, a fuzzy set is a boundary of the translation, which could be mathematically described as (Chaudhari and Patil, 2014):

$$X = \{a, \mu_X(a) : a \in A\} \quad (5)$$

where X corresponds to the name of the fuzzy set, a is the member of the fuzzy set X, $\mu_X(a)$ represents the membership degree of a within the fuzzy set X, and A is the universe of discourse which a is included.

Furthermore, the membership function is a method that translates the input data. However, one of the commonly applied functions is the "triangular membership function", with the membership degree of the output given by (Chen et al., 2015; Yadav et al., 2014):

$$\mu_X(a) = \max\left[\min\left(\frac{a-j}{k-j}, \frac{l-a}{l-k}\right), 0\right] \quad (6)$$

where j defines the horizontal value at the left-most point of the triangular fuzzy set X, k indicates the horizontal value at the centroid of the triangular fuzzy set X, and l suggests the horizontal value at the right-most point of the triangular fuzzy set X.

The fuzzy rule-base inference is the second operation conducted after the fuzzification, as the outputs from the latter are utilized to infer the results according to the constructed "IF-THEN" fuzzy rules. In this work, the "mamdani-type" inference has been applied, which would cause the inferred results to be synthesized in qualitative expressions, e.g., IF NPV is "medium", IRR is "medium", AND BCR is "medium", THEN the result is "medium". The logical operator "AND", consequently, determines the membership degree of the result according to the following (Gupta, 2017):

$$\mu_R(R_i) = \min\left[\mu_N(NPV_i), \mu_I(IRR_i), \mu_B(BCR_i)\right] \quad (7)$$

where i is the fuzzy rule number, $\mu_R(R_i)$ represents the membership degree of the result, $\mu_N(NPV_i)$ corresponds to the membership degree of the NPV, $\mu_I(IRR_i)$ is the membership degree of the IRR, and $\mu_B(BCR_i)$ refers to the membership degree of the BCR.

The third operation of the fuzzy logic, the defuzzification, is a process that translates the qualitative results from the fuzzy rule-base inference into the quantitative outputs, allowing additional mathematics to be operated. In this work, the "centroid of area (COA)" defuzzification technique has been exploited, as all of the inferred outputs are considered to synthesize an appropriate result. Nonetheless, the requirement of this technique is the fuzzy output set, which would provide the necessary components for the calculation as seen below (Xu et al., 2014; Tir et al., 2017):

$$Z = \frac{\sum_{i=1}^{I}\left[\mu_R(R_i) \times \hat{R}_i\right]}{\sum_{i=1}^{I}\left[\mu_R(R_i)\right]} \quad (8)$$

where Z defines the result obtained from the defuzzification, $\hat{R}_i$ is the centroid horizontal value of the fuzzy output set, and I describes the total fuzzy rules employed.

2. MATERIALS AND METHODS

2.1 Materials

In this work, the important details were divided into 3 main parts; an algorithm for investment feasibility assessment, development of an application software, and investigation of the financial information regarding the LED T8 production project, respectively. The former part explained the processes of the feasibility assessment, while in the second part, Microsoft Excel 2010 (Microsoft Inc., licensed by Silpakorn University), has been applied to design the software. The latter part, however, emphasized the financial data of the LED T8 production project, such as sales income, manufacturing expense, considered discount rate, etc., which were provided by Asia Amro Industry Co., Ltd. (Thailand).

2.2 Development of investment feasibility analysis model

This model was used as economic assessment tools in association with the fuzzy logic technique for indicating the feasibility level of the investment project. Particularly, the financial data of the selected project, such as the income, expense, project duration, and floating discount rate, were used as input in the designed model, and then evaluated by the economic feasibility assessment function. Sequentially, the function of investment feasibility analysis utilized the fuzzy logic technique to determine the investment feasibility based on the assessment results. Overall, the operation of the model is shown in Figure 3.

The values of the NPV, IRR, BCR, and DPB were calculated through Equations (1)-(4). These were applied to fundamentally decide if the investment project is economically feasible. In the case of unfeasible, the next operation would be aborted, and the user would be required to adjust the financial data until the project is feasible. The fuzzy logic technique would, further, consider the NPV, IRR, and BCR as the input for the fuzzification to translate into the output of either "low (L)", "medium (M)", or "high (H)", according to the employment of the fuzzy sets described in Figure 4. However, the boundaries of the triangular fuzzy sets were separately explained with its calculations as seen through Equations (9)-(11).

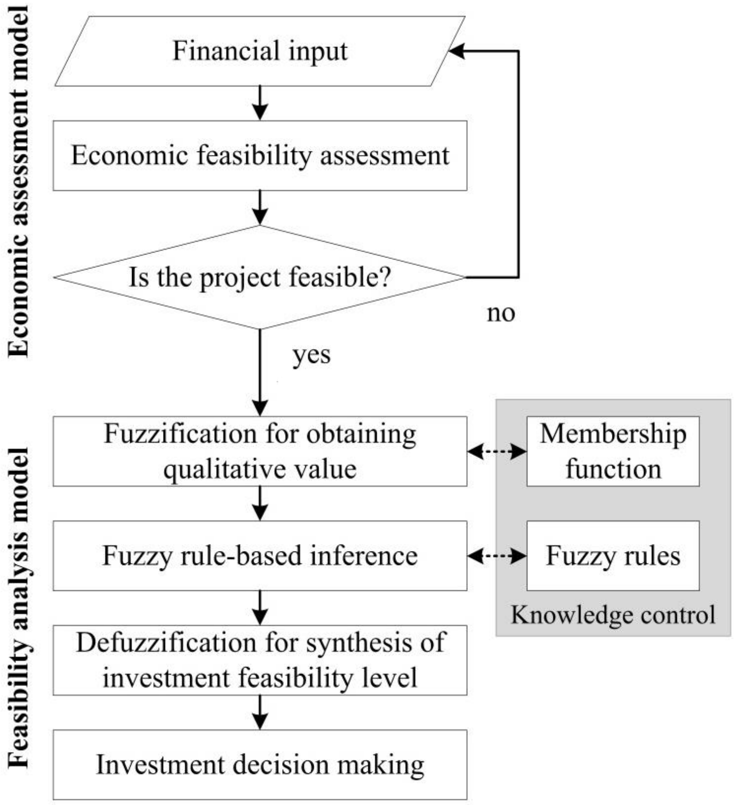

Figure 3 Workflow of investment feasibility analysis model

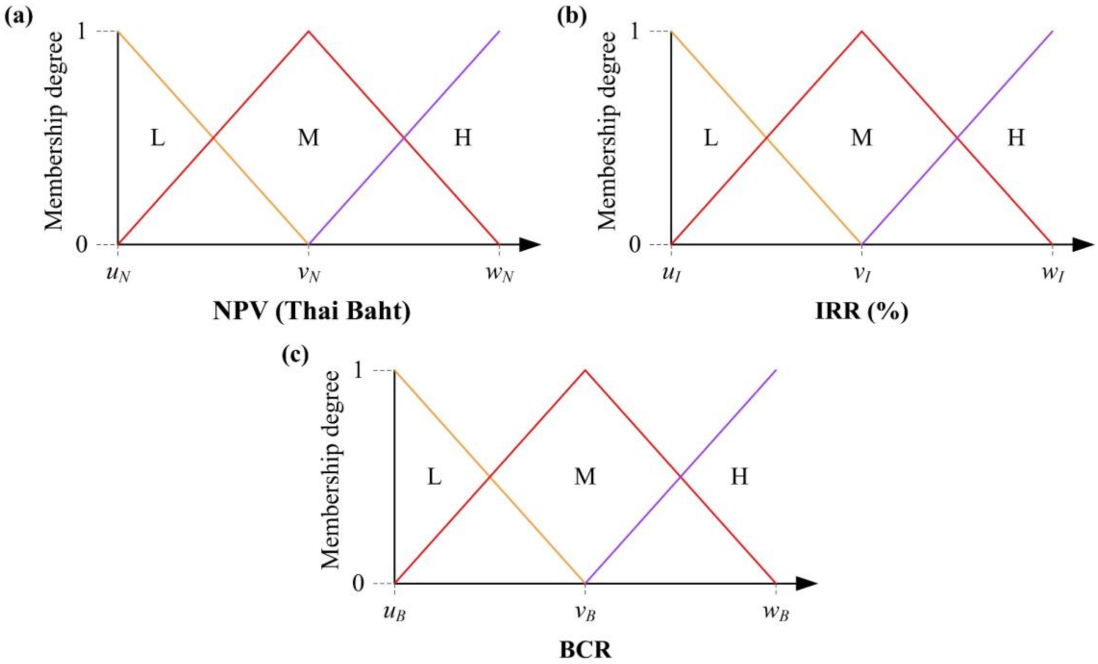

Figure 4 Fuzzy sets applied for fuzzification of (a) NPV, (b) IRR, and (c) BCR

$$u_N = 0, \qquad v_N = \frac{u_N + w_N}{2}, \qquad w_N = \text{EPM} \times \sum_{n=1}^{N} \left[\frac{I_n}{(1+r_n)^n} \right] \tag{9}$$

$$u_I = \frac{\sum_{n=1}^{N}(r)}{N}, \qquad v_I = \frac{u_I + w_I}{2}, \qquad w_I = \text{EPM} + \frac{\sum_{n=1}^{N}(r)}{N} \tag{10}$$

$$u_B = 1, \qquad v_B = \frac{u_B + w_B}{2}, \qquad w_B = \frac{1}{1 - \text{EPM}} \tag{11}$$

Consequently, the fuzzy rule-base inference was conducted to synthesize the desired outputs. Regardless, the result of each fuzzy rule would be determined based on the numerical representations. Explicitly, the fuzzification yields are replaced with numbers, i.e. “low (L)” is converted into “1”, “medium (M)” is changed by “2”, and “high (H)” is equivalent to “3”, respectively. The inferred result would be the summation of these numerical values, causing the possible solution to produce the outcomes from “3” to “9”. Each of these respectively corresponds to the linguistic expression, with “3” and “4” as “poor (P)”, “5” is “low (L)”, “6” for “medium (M)”, “7” translates to “high (H)”, and “8” to “9” convert into “excellent (E)”. In a broader perspective, Table 1 illustrated both the pattern of the fuzzy rules, along with the total 27 rules implemented for the designed model.

Table 1 Fuzzy rules implementation for result inference

Rule no.	IF NPV is		AND IRR is		AND BCR is		THEN Result is		$\widehat{R}_i$ value
1	L	(1)	L	(1)	L	(1)	P	(3)	0.0
2	L	(1)	L	(1)	M	(2)	P	(4)	0.0
3	L	(1)	L	(1)	H	(3)	L	(5)	2.5
4	L	(1)	M	(2)	L	(1)	P	(4)	0.0
5	L	(1)	M	(2)	M	(2)	L	(5)	2.5
6	L	(1)	M	(2)	H	(3)	M	(6)	5.0
7	L	(1)	H	(3)	L	(1)	L	(5)	2.5
8	L	(1)	H	(3)	M	(2)	M	(6)	5.0
9	L	(1)	H	(3)	H	(3)	H	(7)	7.5
10	M	(2)	L	(1)	L	(1)	P	(4)	0.0
11	M	(2)	L	(1)	M	(2)	L	(5)	2.5
12	M	(2)	L	(1)	H	(3)	M	(6)	5.0
13	M	(2)	M	(2)	L	(1)	L	(5)	2.5
14	M	(2)	M	(2)	M	(2)	M	(6)	5.0
15	M	(2)	M	(2)	H	(3)	H	(7)	7.5
16	M	(2)	H	(3)	L	(1)	M	(6)	5.0
17	M	(2)	H	(3)	M	(2)	H	(7)	7.5
18	M	(2)	H	(3)	H	(3)	E	(8)	10
19	H	(3)	L	(1)	L	(1)	L	(5)	2.5
20	H	(3)	L	(1)	M	(2)	M	(6)	5.0
21	H	(3)	L	(1)	H	(3)	H	(7)	7.5
22	H	(3)	M	(2)	L	(1)	M	(6)	5.0
23	H	(3)	M	(2)	M	(2)	H	(7)	7.5
24	H	(3)	M	(2)	H	(3)	E	(8)	10.0
25	H	(3)	H	(3)	L	(1)	H	(7)	7.5
26	H	(3)	H	(3)	M	(2)	E	(8)	10.0
27	H	(3)	H	(3)	H	(3)	E	(9)	10.0

Correspondingly, the COA defuzzification has been applied to translate the linguistic outputs into the quantitative feasibility score (Z). This has been classified into five different feasibility levels, each with its distinctive calculation of the feasibility percentage (Ω), as expressed in the following:

$$\Omega_P = \frac{2.00 - Z}{2.00 - 0.00} \quad , \quad \text{IF} \quad 0.00 \le Z \le 2.00 \tag{12}$$

$$\Omega_L = \frac{4.00 - Z}{4.00 - 2.01} \quad , \quad \text{IF} \quad 2.01 \le Z \le 4.00 \tag{13}$$

$$\Omega_M = \frac{Z - 4.01}{6.00 - 4.01} \quad , \quad \text{IF} \quad 4.01 \le Z \le 6.00 \tag{14}$$

$$\Omega_H = \frac{Z - 6.01}{8.00 - 6.01} \quad , \quad \text{IF} \quad 6.01 \le Z \le 8.00 \tag{15}$$

$$\Omega_E = \frac{Z - 8.01}{10.00 - 8.01} \quad , \quad \text{IF} \quad 8.01 \le Z \le 10.00 \tag{16}$$

The feasibility level and percentage would be automatically interpreted by the model to provide the investment decision-making by following the criteria given in Table 2.

Table 2 Investment decision-making criteria

Feasibility score	Feasibility level	Investment decision
$Z \ge 4.01$	Medium, High, and Excellent	Should be invested
$2.01 < Z < 4.00$	Low	Might be invested
$Z \le 2.00$	Poor	Risky to invest

2.3 Graphical user interface design

In this research work, the investment decision-making model was implemented via the Microsoft Excel program. Specifically, the user was able to interact with the developed software through 2 primary interfaces, namely the financial spreadsheet, and investment analyzer. The former function allowed the user to input the relevant financial data of the investment, as illustrated in Figure 5.

Figure 5 Financial spreadsheet for financial data input

The financial spreadsheet was designed for the input of (a) income, (b) total expense, and (c) profit/loss. However, this investigation considered several types of expense occurred in the project. As such, the total expense has consisted of 5 sub-categories; the initial expense, manufacturing expense, administration expense, financial expense, and corporate income tax. Regardless, the profit/loss would be automatically calculated to inform the analyst of the financial result in each year.

Furthermore, the investment analyzer was an interface comprised of 3 main functions, that is, (d) discount rate and expected profit margin input, (e) economic feasibility assessment results, and (f) investment feasibility analysis, as accordingly detailed in Figure 6.

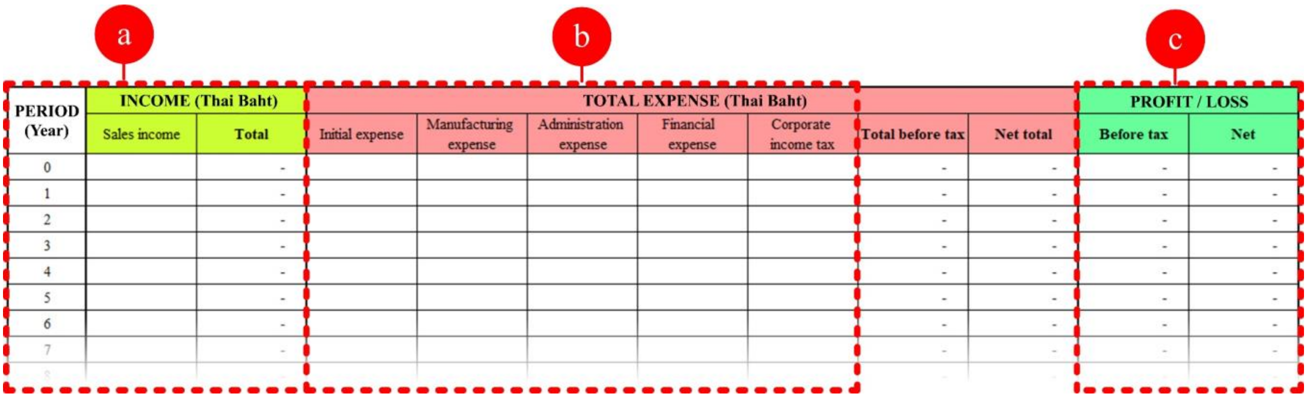

Figure 6 Fuzzy sets applied for fuzzification of (a) NPV, (b) IRR, and (c) BCR

To emphasize, the former permitted the user to input or adjust the floating discount rate (r_n) in each operating year, as well as the EPM of up to 5 values for the margin optimization. The second function indicated the values of the NPV, IRR, BCR, and DPB of the investment. The latter, consequently, demonstrated the relationship between the EPM and the investment feasibility level in percentage in the form of a histogram, and also displayed the decision-making of the considered project.

2.4 Investigation of investment project

To validate the performance of the developed software, the LED T8 lamp production investment project from a Thai manufacturer has been investigated, with its financial data classified into 6 groups, namely the sales income, initial expense, manufacturing expense, administration expense, financial expense, and also corporate income tax. The sales income occurred from the distribution of the LED T8 products at the selling price (S) of 210 Thai Baht for each sold products, with the amount for selling (Q) starting at 87,500 units, and the manufacturing capacity (α_Q) would be increased by 10% every year. However, the distribution assumed that all of the manufactured luminaires could be sold. As the sales income was the only revenue of the project, the total income could be described as:

$$I_n = \left[1 + \alpha_Q\left(n-1\right)\right] \times S \times Q \tag{17}$$

Additionally, the initial expense (E_0) was due to the purchasing and installation of the manufacturing machines, which was evaluated to expend a total of 12,000,000 Thai Baht. Furthermore, the material cost, packaging cost, and also utility cost accounted for the sum (C_Q) of 141 Thai Baht per manufactured units.

The labor cost (C_W) was assumed to be 753,200 Thai Baht in the first year, and would gradually be raised at the rate (α_W) of 5% for the next 5 years. Meanwhile, the maintenance cost (C_M) was anticipated to be at 10% of the machine depreciation cost. Since the machines were to be exploited for 25 years long, the maintenance cost would be constant of annually 48,000 Thai Baht. Consequently, the manufacturing expense of each year ($e_{M,n}$) could be defined in the following Equation:

$$e_{M,n} = \Big[\big[1+\alpha_Q\left(n-1\right)\big]\times C_Q \times Q\Big] + \Big[\big[1+\alpha_W\left(n-1\right)\big]\times C_W\Big] + C_M \qquad (18)$$

Moreover, the administration expense ($e_{A,n}$) was the accumulations of the costs unrelated to the production, such as from the general management, research & development, and office utility cost, etc., which was assessed to be 106,000 Thai Baht in every year. In addition, the financial expense ($e_{F,n}$) was the sum between the interest expense and the loan payback. The interest rate of this investment project corresponded to the floating discount rate (r_n) in each year, while the loan payback was not required to be spent. As such, the financial expense was calculated based on the interest expense incurred from the capital loan (L_0) of 12,000,000 Thai Baht, as given by:

$$e_{F,n} = L_0 \times r_n \qquad (19)$$

Furthermore, the corporate income tax ($e_{T,n}$) would reduce the profit of a business through the rate specifically determined by the revenue department. In this project, the Thailand small to medium enterprise (SME) tax rate was employed. The tax rate is progressive, that is, the first 300,000 Thai Baht of earnings ($P_{T(i)}$) was exempted from any payments, where as the next 2,700,000 Thai Baht ($P_{T(n)}$) would be accounted at the tax rate (T_i) of 15%. Otherwise, the remaining sum was charged with a 20% tax rate (T_n). The depreciation cost (C_D) was defined to be 480,000 Thai Baht each year. Therefore, the SMEs income tax could be expressed as (Thailand Revenue Department, 2016):

$$e_{T,n} = C_{T(i)} + C_{T(n)} \qquad (20)$$

$$C_{T(i)} = \max\Big[\min\Big[\Big(\Big(I_n - e_{M,n} - e_{A,n} - e_{F,n} - C_D - P_{T(i)}\Big)\times T_i\Big), \Big(P_{T(n)} \times T\Big)\Big], 0\Big] \qquad (21)$$

$$C_{T(n)} = \max\Big[\Big(\Big(I_n - e_{M,n} - e_{A,n} - e_{F,n} - C_D - P_{T(i)} - P_{T(n)}\Big)\times T_n\Big), 0\Big] \qquad (22)$$

where $C_{T(i)}$ is the income tax calculated at the rate of 15%, and $C_{T(n)}$ is the income tax calculated at the rate of 20%.

This determined the yearly expense, which was the accumulation of the manufacturing expense, administration expense, financial expense, and also corporate income tax, as seen below:

$$E_n = e_{M,n} + e_{A,n} + e_{F,n} + e_{T,n} \qquad (23)$$

In this investigation, the floating discount rates were correlated to the minimum retail rate (MRR) reported by the Thailand bank, which is effective on the 1st February 2015 to 2019 (Krungthai Bank, 2018; Krungthai Bank, 2019), as detailed in Figure 7(a). Consequently, the EPM of the LED T8 lamp production project was determined to be 20%, according to the illustration of Figure 7(b). Regardless, the project assuming the fixed discount rate at 8.00% has been conducted to verify the impact of the floating discount rate utilization on the investment feasibility.

DISCOUNT RATE & EXPECTED PROFIT MARGIN INPUT				
Discount rate (r_n)		Expected profit margin (EPM)		
Year	r_n	Require no.	EPM	Expected capital
1	8.00%	1	20.00%	17,690,861.57
2	7.88%	2		-
3	7.62%	3		-
4	7.12%	4		-
5	7.12%	5		-

(a) (b)

Figure 7 Considering data from investigated project; (a) floating discount rate, and (b) expected profit margin

3. RESULTS AND DISCUSSION

The financial data applied for the analysis of the floating 7.12%-8.00% and fixed 8.00% discount rate projects were summarized in Table 3 and Table 4, respectively. As seen from the Tables, the significant changes of the financial values between the two projects occurred for the financial expense, corporate income tax, and net profit/loss, of which main cause would be detailed in the experimental results section.

Once the investment feasibility of the LED lighting production project with the given conditions were analyzed, its sensitivity would be investigated. The purpose is to investigate the impact of financial variables on the investment feasibility to provide additional information for risk management in real-world business situations. In this case, the total incomes and expenses of the floating discount rate project were varied by −5% to +5% of their respective original values with an interval of 0.1%.

The investment feasibility has been synthesized, as shown in Figure 8 as an example with the variation of the EPM from 19% to 21% with the interval of 0.5%, and also the floating discount rates were input from 7.12% to 8.00% according to the reported MRR by the Thailand bank (Krungthai Bank, 2018; Krungthai Bank 2019).

Table 3 Summary of financial data for project applying floating discount rate

Year of operation	0	1	2	3	4	5
Discount rate	-	8.000%	7.875%	7.620%	7.120%	7.120%
Sales income (Thai Baht)	-	18,375,000	20,212,500	22,050,000	23,887,500	25,725,000
Initial expense (Thai Baht)	12,000,000	-	-	-	-	-
Manufacturing expense (Thai Baht)	-	13,138,700	14,410,110	15,681,520	16,952,930	18,224,340
Administration expense (Thai Baht)	-	106,000	106,000	106,000	106,000	106,000
Financial expense (Thai Baht)	-	960,000	945,000	914,400	854,400	854,400
Corporate income tax (Thai Baht)	-	543,060	659,278	778,616	903,834	1,017,052
Net profit/loss (Thai Baht)	−12,000,000	3,627,240	4,092,112	4,569,464	5,070,336	5,523,208

Table 4 Summary of financial data for project applying fixed discount rate

Year of operation	0	1	2	3	4	5
Discount rate	-	8.000%	8.000%	8.000%	8.000%	8.000%
Sales income (Thai Baht)	-	18,375,000	20,212,500	22,050,000	23,887,500	25,725,000
Initial expense (Thai Baht)	12,000,000	-	-	-	-	-
Manufacturing expense (Thai Baht)	-	13,138,700	14,410,110	15,681,520	16,952,930	18,224,340
Administration expense (Thai Baht)	-	106,000	106,000	106,000	106,000	106,000
Financial expense (Thai Baht)	-	960,000	960,000	960,000	960,000	960,000
Corporate income tax (Thai Baht)	-	543,060	656,278	769,496	882,714	995,932
Net profit/loss (Thai Baht)	−12,000,000	3,627,240	4,080,112	4,532,984	4,985,856	5,438,728

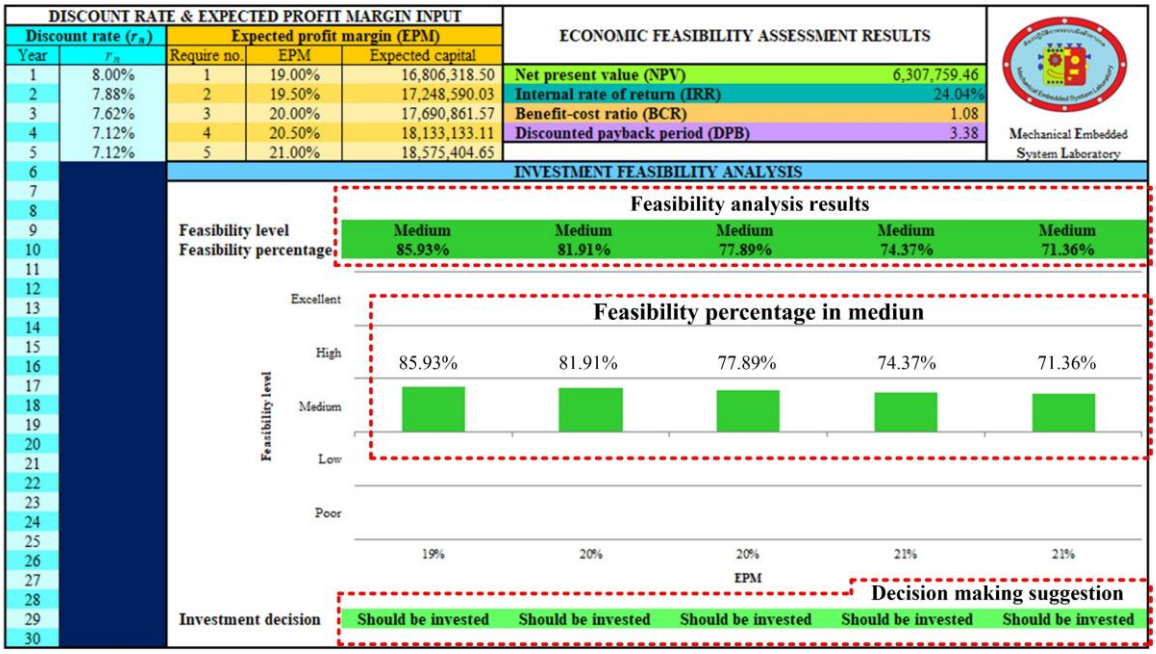

Figure 8 Example of output results obtained from developed software

It is demonstrated that the developed software could synthesize the investment feasibility of a given project. Additionally, it could be observed that if the EPM was lowered, the feasibility percentage would be increased. In contrast, by raising the EPM value, the feasibility percentage was reduced. Consequently, it could be interpolated that the variation of the EPM inversely affected the investment feasibility level and percentage. Furthermore, the example shown that while fundamental of economic assessment tools of NPV, IRR, BCR, and DPB could be given, the developed software could also synthesize the investment feasibility as well as investment decision. Traditional economic feasibility analyses tend to conclude the feasibility of given projects while the decisions to invest would be dependant on the investors or financial analysts. By applying the fuzzy logic technique, the proposed model could perform the mentioned analyses as well as synthesize the feasibility level and percentage of such projects. Additionally, investment decisions could be determined objectively, thus putting less burden to the investors or financial experts. This implies the novelty of the developed software to perform the investment feasibility analyses and decision making with less human requirement.

Regardless, the analyses of the LED T8 lamp production project applying either the floating or fixed discount rate have been conducted. As mentioned in the investment project investigation, the financial expense, corporate income tax, and net profit/loss values differed between the floating and fixed discount rate projects, by which details were summarized in Table 5.

Table 5 Capital difference of floating discount rate project compared to fixed rate project

Year of operation	1	2	3	4	5
Financial expense (Thai Baht)	-	−15,000	−45,600	−105,600	−105,600
Corporate income tax (Thai Baht)	-	3,000	9,120	21,120	21,120
Net profit/loss (Thai Baht)	-	12,000	36,480	84,480	84,480

As seen from Table 5, the financial expense of the investment projects was affected by the discount rate variation, which consequently caused the change in the values of the corporate income tax and net profit. The financial expense of the project with the floating discount rate was indicated to be lower than the fixed rate. However, the corporate income tax of the former was higher, due to the reduction in the expense caused the earnings before tax to be raised. Nevertheless, the changes in the financial expense outweighed the variation in the income tax, and resulted in the net profit of the floating rate to be greater. Moreover, the investment feasibility of the project with the floating and fixed discount rate has been analyzed, of which results were compared (Table 6).

Table 6 Investment feasibility comparison between projects applying floating and fixed discount rate

Results	Floating discount rate project	Fixed discount rate project
NPV (Thai Baht)	6,307,759.46	5,821,282.71
IRR (%)	24.04	23.70
BCR	1.08	1.07
DPB (years)	3.38	3.42
Feasibility level	Medium	Medium
Feasibility percentage (%)	77.89	67.34
Investment decision-making	Should be invested	Should be invested

The investment feasibility of the project utilizing the floating discount rate was greater. Both projects had the feasibility level of “medium”, and were suggested to be appropriate investments. However, the economic feasibility parameters of NPV, IRR, BCR in the floating discount rate project had more values than the fixed-rate project, thereby synthesizing a more attractive feasibility percentage of 77.89% than the fixed-rate project with the percentage of 67.34%. The lesser value in DPB suggested the floating rate project would break-even faster. Ultimately, it was implied that the floating discount rate causes the project to be more preferable for an investment.

The interest rate of the project might be varied due to the operation policy of the financial institutes. In this case, the financial analyst has assessed that the rate might be increased by 3% from the original rate as considered before. As such, the investment feasibility of both the projects with the floating and fixed-rate have been studied under the addition of the discount rate, with values from 0% to 3% and the interval of 0.1% (Figure 9).

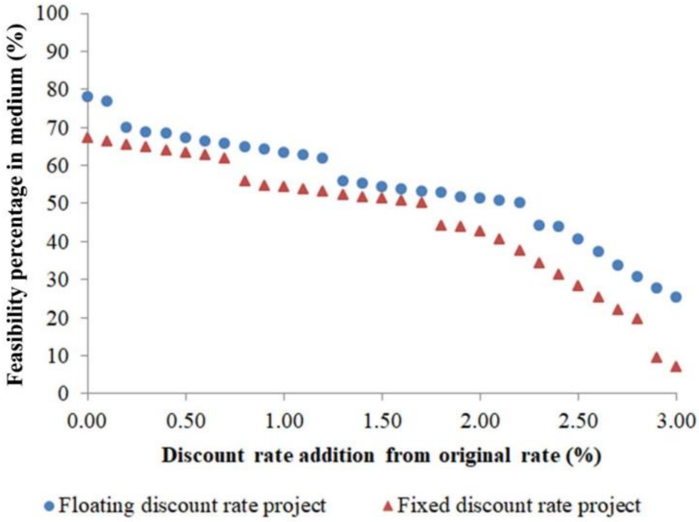

Figure 9 Analysis of feasibility percentage under discount rate addition from original rate

It was found that the investment feasibility levels of both projects were “medium”, though at a different percentage. The floating discount rate project had a higher feasibility percentage than the fixed rate regardless of the discount rate addition. This implied that the floating discount rate causes the investment project to be more attractive than the fixed rate. Therefore, the implementation of the floating discount rate function could improve the analysis performance of the developed software to synthesize more realistic results than the traditional analysis model.

To further investigate the investment feasibility of the LED lighting production project in uncertain situations, the sensitivity analysis of its essential financial factors have been carried out. By varying the total incomes and expenses of the floating discount rate project from −5% to +5% with 0.1% of interval, the investment feasibility of the project are presented in Figure 10(a) and (b), respectively.

From Figure 10(a) and (b), the critical point in which the investment feasibility level would transition from “medium” to “low” was illustrated. It presented risk factor for the project, as the decision to invest changed from “should be invested” to “might be invested”. For the case of total incomes, it is suggested that the project could become less attractive for an investment if the total incomes were lowered by 3.1% or more from its original value. In contrast, increase of 2.4% and onward in total expenses would cause the project to be less feasible. Therefore, the aforementioned factors should be considered and managed appropriately for the economic feasibility of the investment project.

Total incomes of the LED lighting production project mainly resulted from the sales income of the produced LED goods. Thus, it could be assumed that a decrease in sales amount affected total incomes of the project. Since sales amount depended on market demand, marketing and promotions would be recommended to keep customer demand in an optimum level. For the factors which affected the increase in total expenses, there were the manufacturing expense, initial expense, administration expense, financial expense, and corporate income tax. However, corporate income tax was more dependent on government policies and directly proportional to the project's profit, thus this parameter could hardly be controlled and should not be much considered. In this case, the variable that should be optimized ought to be the manufacturing expense, as it increased in proportion to production amount, a parameter which also affected the sales income. Therefore, the porject's profit would mainly depend on the difference between sales income and manufacturing expense. To optimize the investment feasibility, it is suggested that associated production cost (e.g. labor cost, material cost, packaging cost, etc.) should be carefully managed.

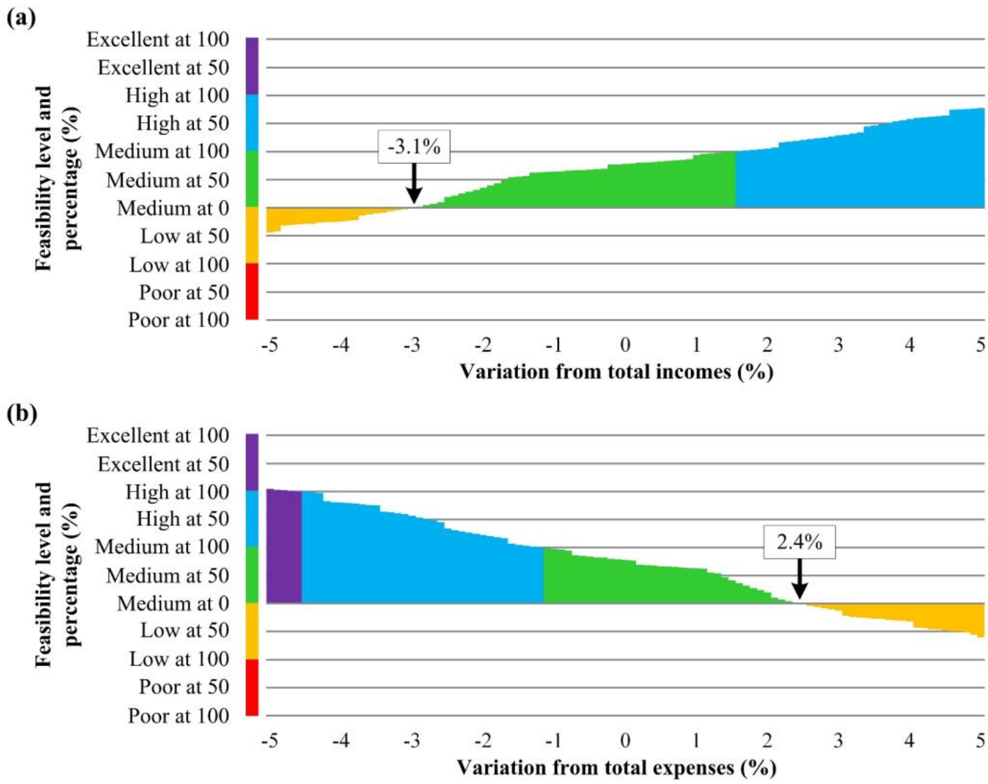

Figure 10 Sensitivity analysis of financial variables; (a) total incomes and (b) total expenses

4. CONCLUSION

In this research, an application software for the investment feasibility analysis of the LED T8 lamp production project has been developed with the floating discount rate function for SME project consideration. After the investigation using the economic assessment tools (NPV, IRR, BCR, and DPB) in associate with the fuzzy logic technique, it was found that a 5-year duration project applying an EPM of 20% and also 7.12-8.00% of floating discount rate has a feasibility level of "medium" at 77.89%. An equivalent project utilizing a fixed discount rate instead was less attractive with synthesized level of "medium" at 67.34%. In addition, the discount rate variation, ranging from 0% to 3% with interval of 0.1% has been analyzed, of which indicated that the feasibility of the floating discount rate project was still more preferable. Thus, utilization of floating discount rate could improve the feasibility of the project. Moreover, sensitivity analysis of the total incomes and expenses have indicated that the project would be less likely to invest (might be invested) when the parameters were changed by –3.1% and 2.4%, respectively. However, fluctuations of sales income and manufacturing expense were suggested to be sensitive on the project feasibility. Therefore, the developed application software could be suitable for assisting in a more realistic decision-making under real economy. Nonetheless, financial analyst would be required to input the discount rate. As such, an automatic function for prediction of the discount rate is recommended for future work.

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